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LABORATORY STUDIES OF MOUNTAIN STRUCTURES.

(A Report of Progress.)

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Several investigators have used the compression box type of machine for the study of mountain structures in the laboratory, but so far as I know, no one else has used a machine of such dimensions as that constructed by Stone, with the face of the thrust block at an angle other than ninety degrees to the direction of thrust (1). My first investigations were begun using a modification of this machine in order to study structures produced by thrusting, the thrust being transmitted by the advance of a thrust block the face of which was at an angle of forty-five degrees to the direction of thrust. Since starting the work it has seemed advisable to study the results obtained by the use of the unmodified machine as well as those obtained by the use of the modified machine (2).

The materials used are layers of clay to represent incompetent strata and paraffine to represent the competent strata. In the early stages of our work at Muskingum College, Stone experimented with Plaster of Paris for the competent layers, but found it too brittle and faulted rather than folded. In all my work I have used pure paraffine for the competent strata. As the paraffine layers represent the competent strata their thickness is an important factor and will be given in all cases.

In these studies the blocks to be compressed were built of two layers of clay separated by a paraffine layer and capped by another paraffine layer. An overburden of sand was piled on top to give pressure corresponding to the weight of younger strata and the block was shortened seven inches. In the earlier stages of our work various combinations of clay and paraffine layers were used and in no case was any attempt made at uniformity of thickness of the individual paraffine layers. These layers varied from paper thin to three-sixteenths of an inch in thickness. In all cases the thrust was transmitted by a block the face of which advanced at an angle of forty-five degrees to the direction of thrust. Later experiments were tried, and are still being tried, in which uniformity of paraffine layers has been maintained. In some cases the thrust is transmitted by a block the face of which advances at an angle of forty-five degrees to the direction of thrust and in other cases the face of the block advances at ninety degrees to the direction of thrust.

Some of the experiments are here described and tentative conclusions drawn from the results. We are continuing these studies and plan to carry on field studies in connection with our laboratory experiments in the hope that we might get more definite results, but we are of the belief that some of our preliminary results and tentative conclusions may be of interest.

For the sake of clearness in describing the results let us suppose that the thrust comes from the east, then the side of the block opposite the thrust will be the west. Thus we can speak of the various portions of the block in terms of direction.

A block was made in which the lower paraffine layer varied from three-eighths of an inch in thickness at the south side of the block to paper thin at the north side of the block. The top layer of paraffine was of similar thickness.

On the side of the block nearest the thrust, where the paraffine was thickest, the layers folded once into an asymmetrical anticline having its steeper side next to the thrust. The crest of the anticline broke thus causing a fault to develop. On the west side of the block, where the paraffine layers were thick, the layers rode up on the confining wall. Toward the north side of the block, near the thrust, a series of small asymmetrical folds developed. This seems to indicate that the thrust was transmitted much better by the thick layers than by the thin ones.

Across the block at the west side, where the paraffine layers were thin, the top layer broke into a series of asymmetrical folds which were parallel to the face of the thrust block. It will be noted by reference to Figure 1 that these folds are slightly arcuate.

Another block was formed in which the bottom paraffine

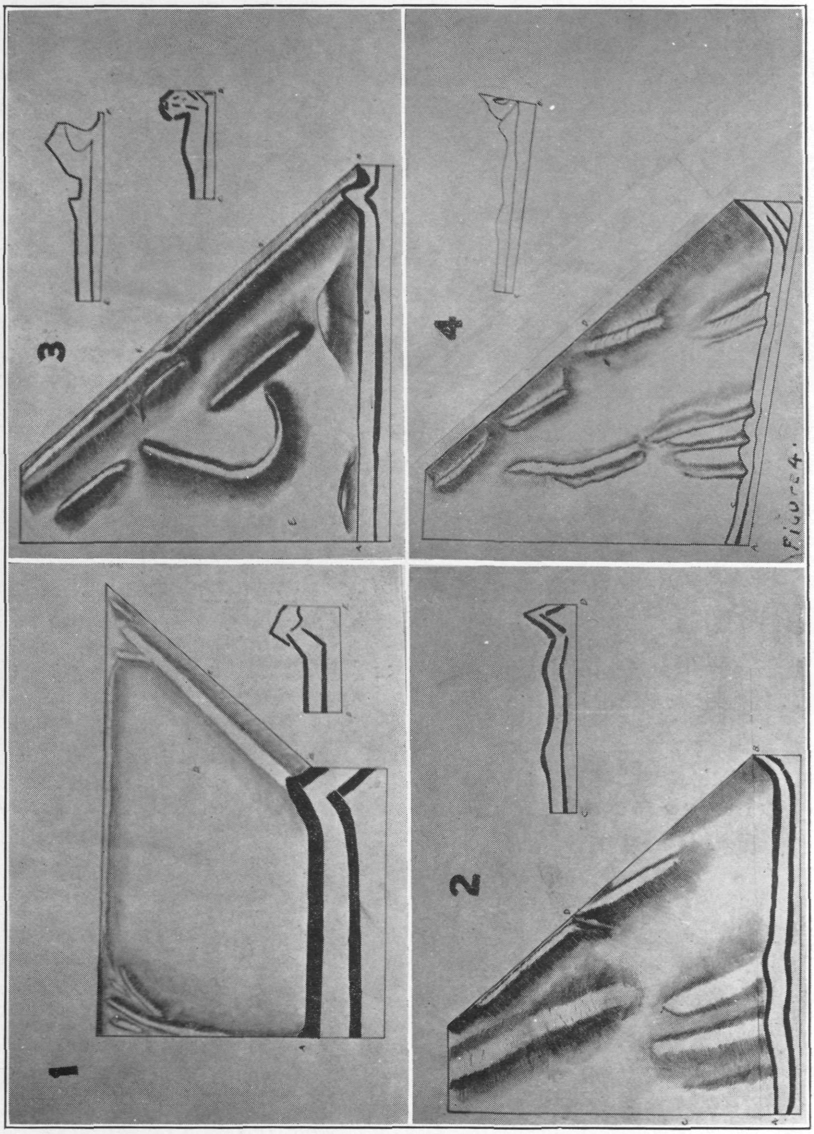
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Figure 4.
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layer was from three-sixteenths of an inch to one-quarter of an inch in thickness. The top layer varied from one-eighth of an inch to five-sixteenths of an inch in thickness, thickening toward the thrust block.

On the south-east side of the block the layers rode up on the thrust block. Farther north along the thrust block an asymmetrical anticline developed having its steeper side next the thrust block. Beginning about the place where this anticline developed a symmetrical anticline developed parallel to the face of the thrust block and at a distance from it. Near the south-west corner of the block a series of folds developed parallel to the face of the thrust block.

These results indicate that where the competent layers are thick the thrust is transmitted easily and a few larger folds result. (Figure 2.)

In another block the bottom layer of paraffine varied from one-eighth of an inch to five-sixteenths of an inch in thickness, being thinner near the thrust block. The top layer was paper thin on the west side, thickening to three-eighths of an inch at the east side.

On the east side of the block, where the paraffine layer was thickest, the layers were folded into an asymmetrical anticline the steeper side of which was to the west. At the south-east corner of the block a large asymmetrical syncline formed, the steeper side of which was away from the thrust. On the limb of the anticline near the thrust, in the top paraffine layer, a series of five small folds were formed. These folds amounted to small wrinkles on the surface of the paraffine and were due to the compression of the layer into a smaller area. Toward the north-east corner of the block, where the paraffine was thin, a series of small asymmetrical folds were formed parallel to the face of the thrust block.

Midway across the block, with one end joining the previously described anticline at a point where the anticline breaks into several folds, was a hook-shaped anticline resembling a large reversed J. This developed only on the surface layer. The steeper side of this fold was toward the east. The peculiar shape of the fold was probably due to the force resultant of the several forces acting—the active thrust and the stationary blocks. From the barb of the hook-like anticline there extended a small asymmetrical anticline parallel to the face of the thrust block. (Figure 3.)

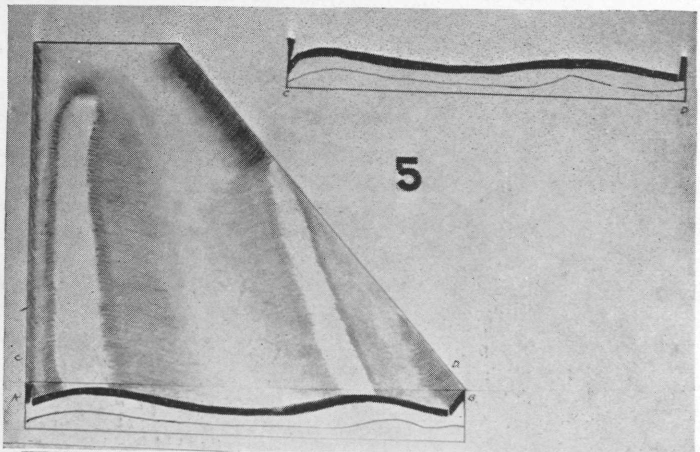
A block in which the basal paraffine layer varied from three-sixteenths of an inch to paper thin and the top layer of which varied from one-sixteenth of an inch to paper thin was subjected to a thrust similar to that to which the other blocks were subjected.

Along the east side of the block the layers folded upward riding up on the thrust block. The fold was broken on the flank by a series of smaller folds having the steeper side toward the west. Because the competent layers were too thin to transmit the thrust for any great distance the folds broke into a number of smaller ones. Near the south-east side of the block a series of small folds developed in the top layer. These folds made an angle with the face of the thrust block joining the upthrust portion about fourteen inches from the south side of the block. About half way across the block, in the top layer, there was a series of parallel folds almost parallel to the face of the thrust block but making a slight angle with it. These folds were low and small. They parallel the face of the thrust block for a short distance then swing around parallel to the west wall of the machine. Note that this fold curves. (Figure 4.) The bottom layer of paraffine was unaffected except by slight thickening at the ends of the block and faulting near the thrust block.

Another block was deformed in a similar way. This block was built as the others but the bottom paraffine layer was paper thin and the top paraffine layer varied from a quarter to a half inch in thickness. (Figure 5.)

Near each end of the thrust block the thick paraffine layer rode up on the block. At a distance of about five inches from the thrust block, measured along the south edge, a large, gentle fold developed at an angle to the face of the thrust block and meeting it about eighteen inches from the south-east corner of the block. Across the block near the west wall an asymmetrical anticline developed having the steeper side away from the thrust. The paraffine layer rode up on the west wall. The bottom paraffine layer had a few small folds and faults not coincident with those above. This experiment shows that the thrust is best transmitted by the thicker layers and that folds are fewer in number and of greater magnitude.

As has already been suggested some of our later experiments have been carried on using both the modified and unmodified machine with special effort being made to maintain uniformity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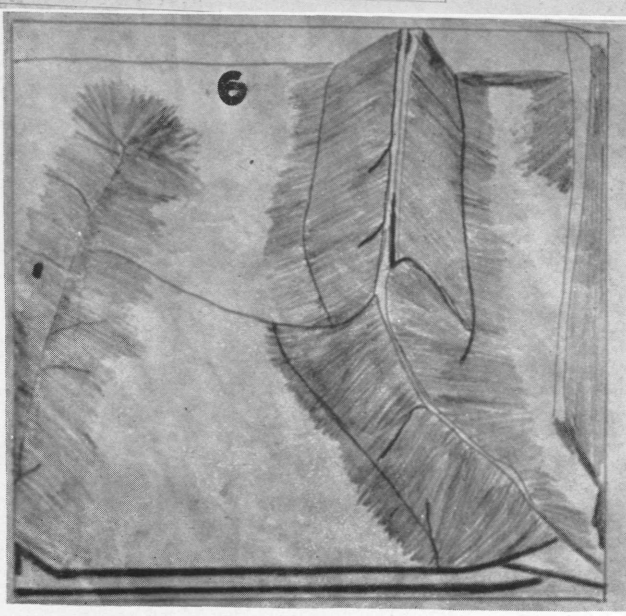
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of thickness of the individual paraffine layers. We are at present engaged in such studies varying the thickness of the paraffine layers and trying various combinations in order to find, if possible, the mathematical relationship between thickness of competent layers and number and magnitude of folds.

In one of these experiments the paraffine layers were five-sixteenths of an inch in thickness. The block was shortened eight inches by the advance of a thrust block the face of which advanced at an angle of ninety degrees to the direction of thrust.

The layers rode up on the thrust block. An arcuate anticline formed three inches from the thrust block along the south side and nine and one-half inches from the thrust block at the north side. Along the west wall a small fold formed having its steeper side toward the west. All these folds were greatly faulted. One fault developed along the crest of the anticline and numerous others at right angles down the limbs of the folds. (Figure 6.)

A number of arcuate folds were formed both in blocks in which no effort was made to maintain uniformity of competent layers as well as in blocks where uniformity was maintained. They formed in blocks which were compressed in the modified machine and those which were compressed in the unmodified machine.

The experiments here described are a few of those performed but they serve to illustrate some of the results from which the following tentative conclusions have been drawn. There seems to be a relationship between the thickness of the competent layers and the number and magnitude of the folds. Exactly what this relationship is we cannot state with mathematical accuracy, but our results seem to indicate that where the competent layers are thick a few large folds are formed and where the competent layers are thin numerous small folds develop. At present we are carrying on investigations using competent layers of uniform thickness in the hope of discovering the mathematical relationship between the thickness of the competent layers and the number and magnitude of the folds.

These experiments also show that even though the top layers are deformed the bottom layers do not necessarily deform in a similar manner but may find relief by thickening. This may be due to the additional weight of the strata above or the fact that the lower layers may be in the zone of flowage.

The factors influencing the character, location and magnitude of folds are therefore:

1. Thickness and competency of the layers involved.
2. The forces or combination of forces involved in producing the folds.
3. The overburden.

Unfortunately, studies of this sort are suggestive rather than conclusive. As Stone suggested to the Geology section at the 1930 meeting of the Ohio Academy of Science, we cannot reproduce field conditions to scale in the laboratory because field investigators have failed to give us the needed data as to crushing and tensil strengths of the rocks involved in such structures. If we had such data we might reproduce on a small scale observed geologic structures and arrive at some conclusions as to their mode of origin.

LITERATURE CITED.

1. **Stone, Alan.** Science, Vol. LXXII, No. 1863, Sept. 12, 1930, p. 276.
2. **Mitchell, R. H.** Science, Vol. LXXII, No. 1863, Sept. 12, 1930, pp. 275–76.

Spectroscopy.

This book is highly recommended to those who wish to have, in an interesting and convenient form, a discussion of the apparatus, technique and data involved in the study of Spectroscopy. The book fills a long felt need for an introductory text on this subject which might be easily understood by scientists in other fields (particularly in Analytical, Organic and Bio-Chemistry). The author suggests method of procedure together with examples of data and their interpretation. There is an absence of a suitable bibliography; and an overemphasis of the author's personal contributions detract slightly from the volume.
—WALLACE R. BRODE.

Spectroscopy, by S. Judd Lewis. 91 pp. London, Blackie and Son, Ltd., 1933.

Petroleum.

Here are brought together the results of five years research carried on at various places in the United States upon material collected from all over the world. There are dealt with in the various chapters the following major subjects: collection and preparation of samples; measurement of organic content; distillation tests; texture; calcium carbonate content; relation of organic matter to environment; detailed analyses of organic constituents of sediment; change in organic content with depth; comparison of past and recent sediments; and theoretical considerations. It is a definite contribution to the understanding of the possible origin of the source beds of petroleum.—WILLARD BERRY.

Origin and Environment of Source Sediments of Petroleum, by P. D. Trask, assisted by H. E. Hammar and C. C. Wu. xv+323 pp. Houston, Gulf Publishing Co., 1932. $6.00.